Energy and buildings

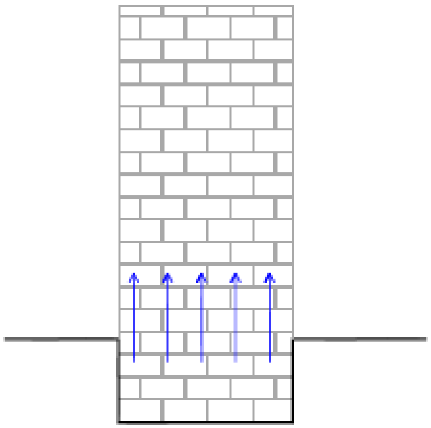
Interstitial condensation in buildings

Content

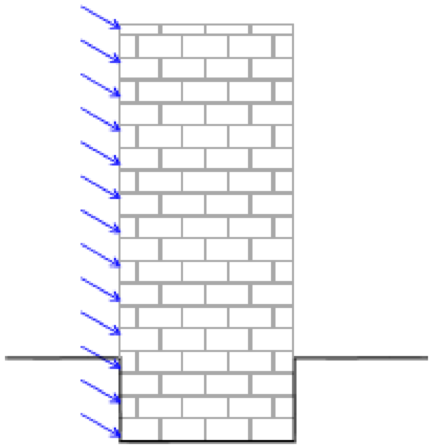
Interstitial condensation

Water in building structures

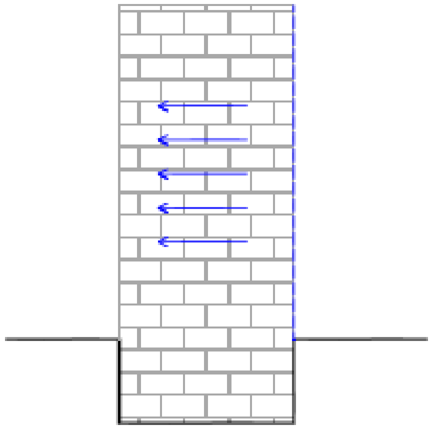
1) RISING DAMP



2) SEEPAGE



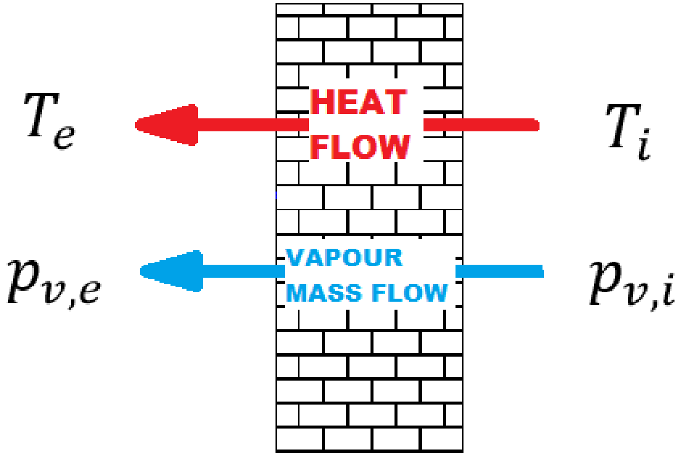
3) CONDENSATION



Interstitial condensation

Definition

Interstitial condensation occurs when the **moist air** migrating from the indoor to the outdoor environment **reaches the dew point temperature within the fabric.**



Interstitial condensation

Definition

Interstitial condensation occurs when the **moist air** migrating from the indoor to the outdoor environment **reaches the dew point temperature within the fabric.**

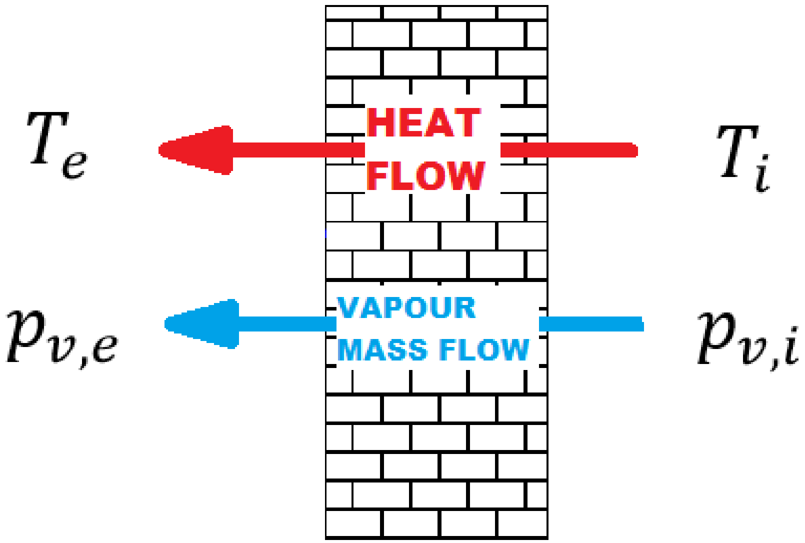
CONSEQUENCES

- Problems of water disposal inside the masonry
- Loss of thermal and structural performance of construction materials
- Formation of mould

Interstitial condensation

Definition

Water vapour diffusion is due to the water vapour partial pressure gradient between inside and outside.



Interstitial condensation

Fick's Law

One-dimensional, **steady state diffusion** in homogeneous materials

$$J = -D\frac{dc}{dx}$$

J = diffusion flux density

D = water vapour diffusion coefficient in the considered material [m^2/s]

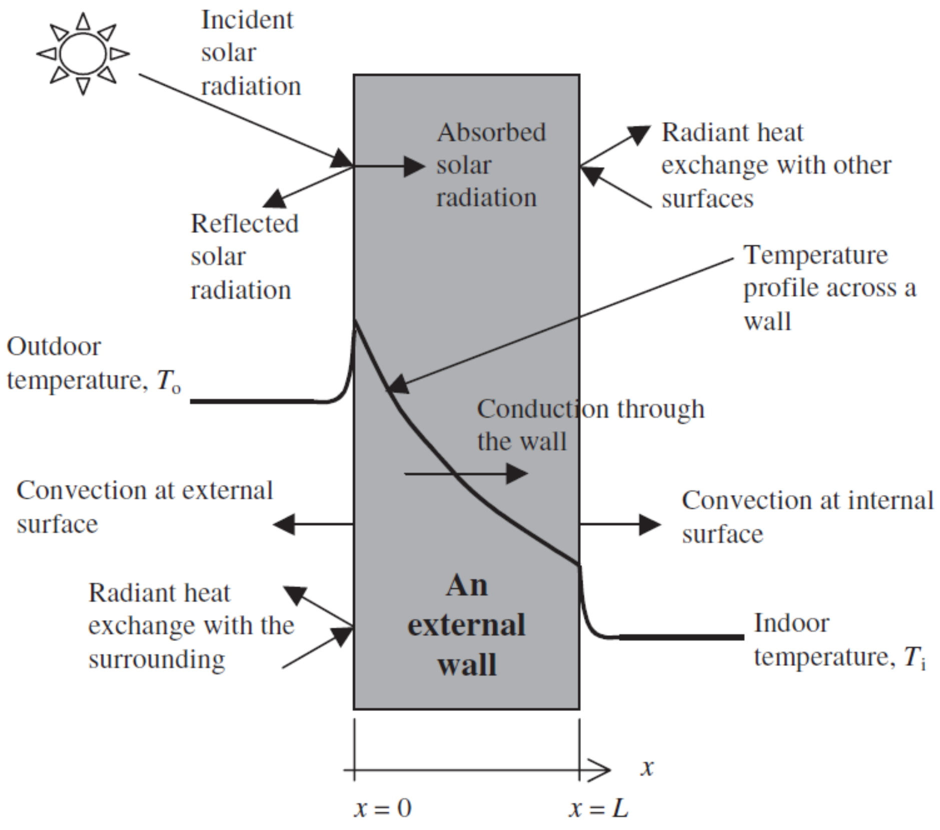
c = concentration (e.g. partial pressure)

x = position in the diffusion direction [m]

Interstitial condensation

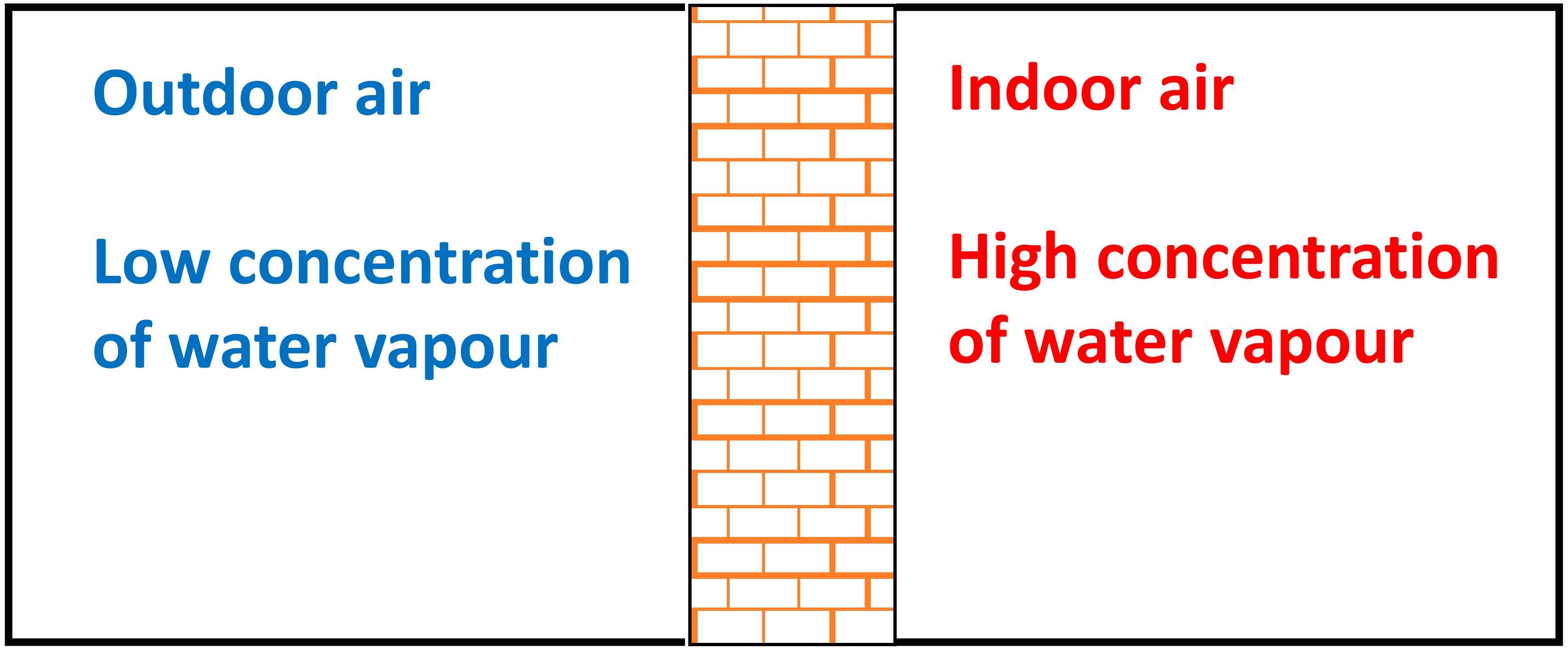
Assumptions

- One-dimensional problem
- Steady state
- Homogeneous materials
- No air movement (only in ventilated cavities)
- No solar radiation



Interstitial condensation

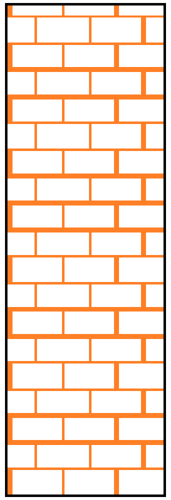
Water vapour permeability



Interstitial condensation

Water vapour permeability

$$g = \delta_P \frac{\Delta p}{d}$$



g: Moisture (water vapour) transfer rate [kg/s]

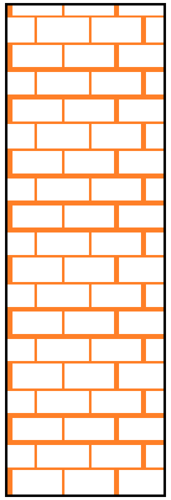
δ_P: **water vapour permeability of the construction material** with respect to partial vapour pressure [kg/(m·s·Pa)].

d: thickness of the material [m]

Interstitial condensation

Water vapour permeability

$$g = \frac{\delta_0}{\mu}\frac{\Delta p}{d}$$



g: Moisture transfer rate [kg/(s m²)]

δ_0: water vapour permeability of the air with respect to partial vapour pressure = $2 \cdot 10^{-10}$ kg/(m·s·Pa).

μ: water vapour resistance factor [-]

Interstitial condensation

Water vapour permeability of construction materials

Material		ρ [kg/m3]	μ [-]
Concrete (closed structure)	Aggregated concrete	2000-2400	75-155
	Clay concrete	1000-1700	75-110
Concrete (open structure)	Clay concrete	500-1000	6-11
	Aerated concrete	400-800	6-11
	Perlytes	250-400	5-14
Thermal insulation materials	Glass wool	22-165	1
	Mineral wool	30-150	1-2
	Wood fibers	50-400	1-5
	Polyurethane (PUR)	25-50	30-50
	Waterproof polyurethane (PUR)	25-50	100-200
	Polyethilene (XPS)	15-40	80-150
	Polyethilene (EPS)	15-40	20-110
Plasters	Gypsum plaster	600-1200	11
	Lime and chalk plaster	1400	11
	Chalk	1800	17-40
Bricks	Hollow bricks	600-1000	6-11
	Semi-hollow bricks	1200-2000	6-11

Interstitial condensation

Equivalent air layer thickness

$$g = \frac{\delta_0}{\mu}\frac{\Delta p}{d} = \delta_0 \frac{\Delta p}{s_d}$$

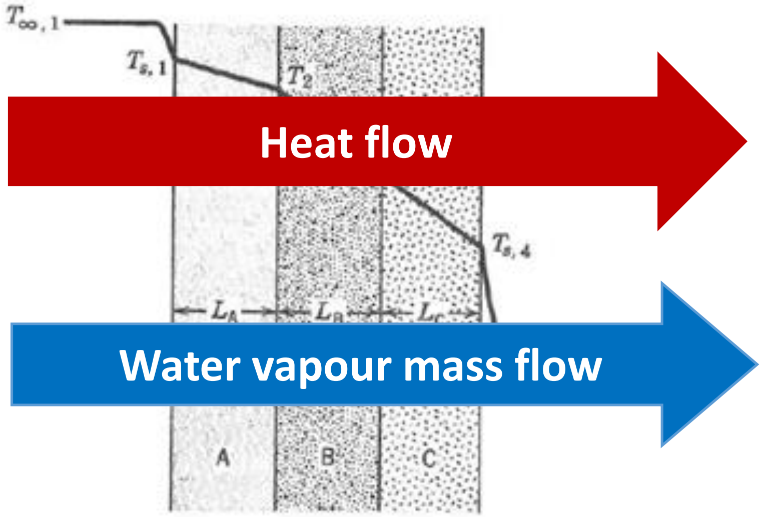
s_d [m] water vapour diffusion-equivalent air layer thickness

Interstitial condensation

Thermal analogy for a composite wall

T_i

$p_{v,i}$



T_e

$p_{v,e}$

$$g = \delta_0 \frac{\Delta p}{s_d}$$

$$g = \frac{\Delta p_v}{\sum_i \frac{s_d}{\delta_0}}$$

Interstitial condensation

Thermal analogy for a composite wall

Heat balance	Water vapour mass balance
Heat flow rate, ***q***	Moisture transfer rate, ***g***
Temperature difference, ***ΔT***	Partial water vapour pressure difference, $\boldsymbol{\Delta p_v}$
Thermal resistance, **R** $=\sum_i \frac{d_i}{k_i}$	Resistance to water vapour diffusion, **Z** $=\sum_i \frac{d_i}{\delta_i}$

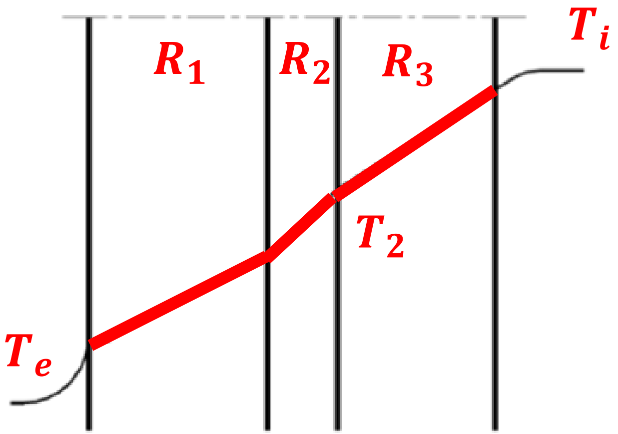
$$g = \frac{\Delta p_v}{\sum_i \frac{d_i}{\delta_i}}$$

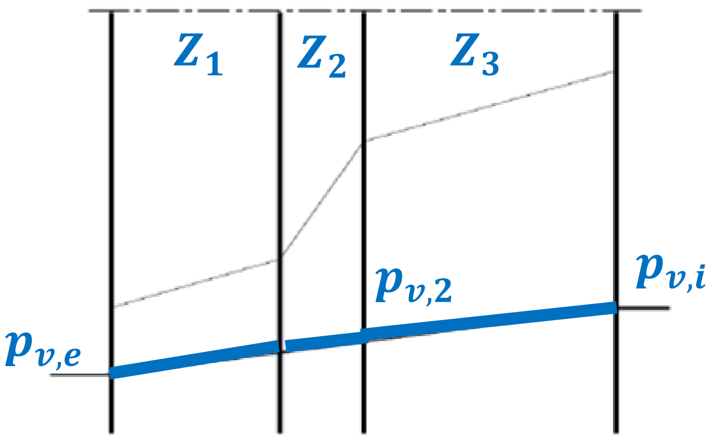
$$g = \frac{\Delta p_v}{\sum_i \frac{\mu_i d_i}{\delta_0}}$$

$$g = \frac{\Delta p_v}{\sum_i \frac{s_{d.i}}{\delta_0}}$$

Interstitial condensation

Thermal analogy for a composite wall





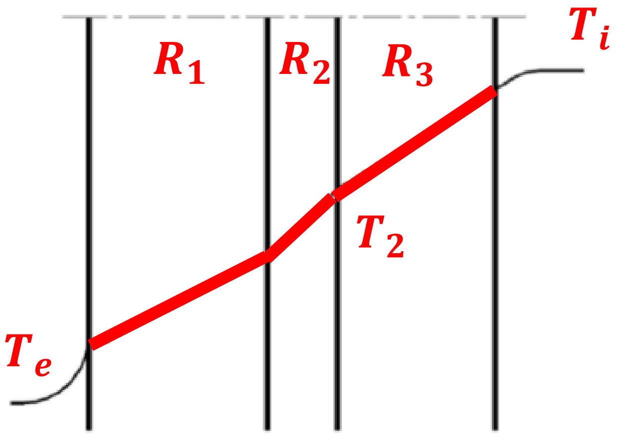
$$Z_j = \frac{s_{d.j}}{\delta_0}$$

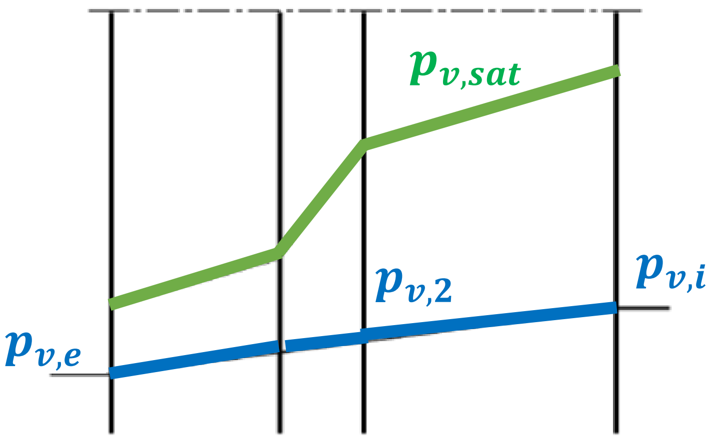
$$T_j = T_e + \frac{\sum_{l=1}^{j} R_j}{R}\,(T_i - T_e)$$

$$p_{v,j} = p_{v,e} + \frac{\sum_{l=1}^{j} Z_j}{Z}\,(p_{v,i} - p_{v,e})$$

Interstitial condensation

Thermal analogy for a composite wall





$$T_j = T_e + \frac{\sum_{l=1}^{j} R_j}{R} (T_i - T_e)$$

$$p_{sat,j} = \mathrm{f}(T_j)$$

Does the moist air reach the dew point inside the structure?

$$p_{v,j} < p_{v,sat}(T_j)$$

Glaser method

Purpose

The Standard ISO 13788 describes a method to establish the **annual moisture balance** and to calculate the **maximum amount of accumulated moisture** due to interstitial condensation.

The method is an assessment rather than an accurate prediction tool. It is suitable for comparing different constructions and assessing the effects of modifications.

Glaser method

Purpose

- It does not provide an accurate prediction of moisture conditions within the structure under service conditions.
- A detailed evaluation of the non-steady transfer of heat and moisture through building structures can be performed with other calculation methods, as described in **EN 15026 Standard** *Hygrothermal performance of building components and building elements - Assessment of moisture transfer by numerical simulation*.

(such as WUFI PRO software developed by Fraunhofer Institut IBP)

Glaser method

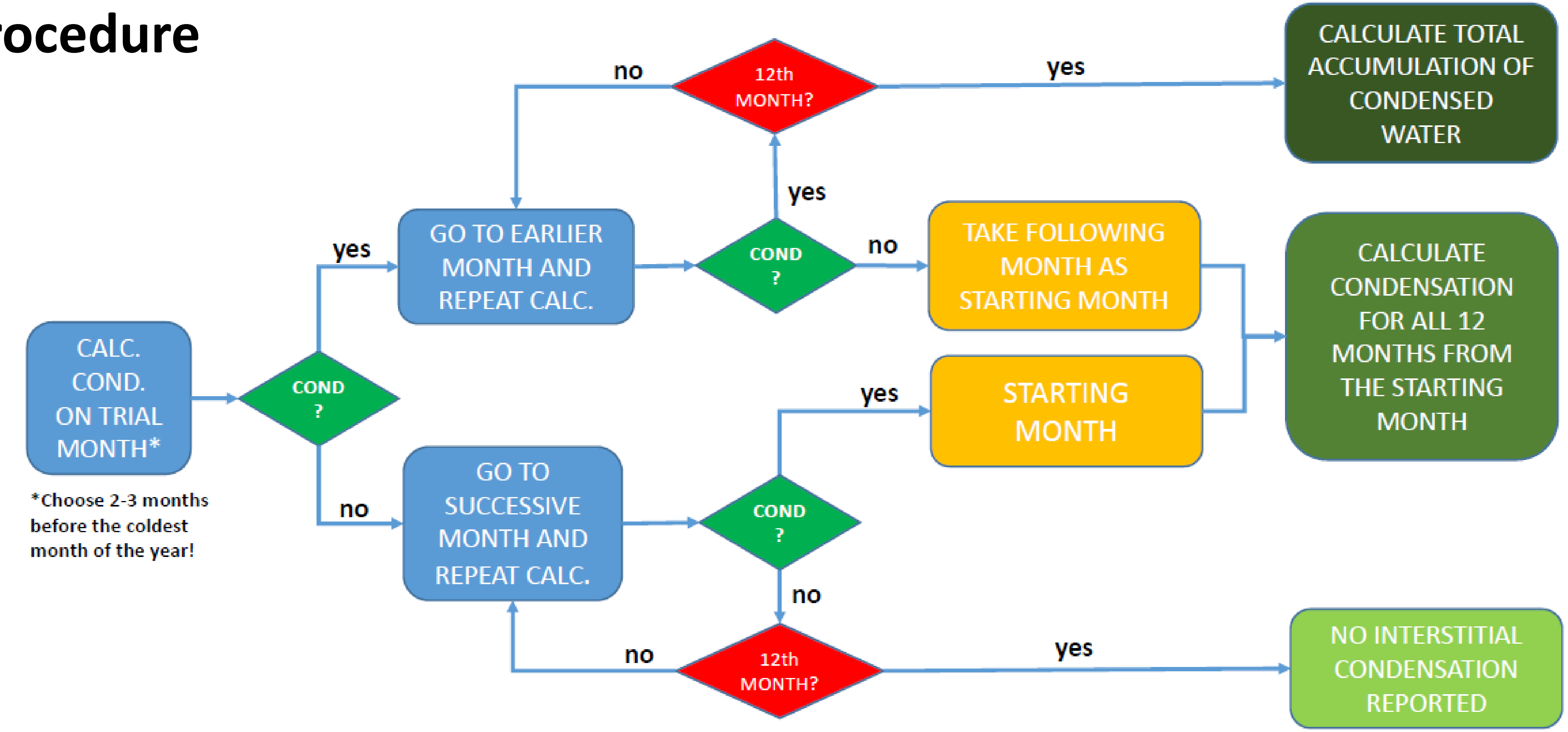
Procedure

The same boundary conditions are set as for the surface condensation calculation (ISO 13788).

1) **External boundary condition** according to UNI 10349 (mean monthly external air temperature and partial water vapour pressure);
2) **Internal boundary conditions** according to one of the three methods prescribed by ISO 13788;
3) Find the **starting month**, then carry out the **calculation for each month** starting from the starting month.

Glaser method

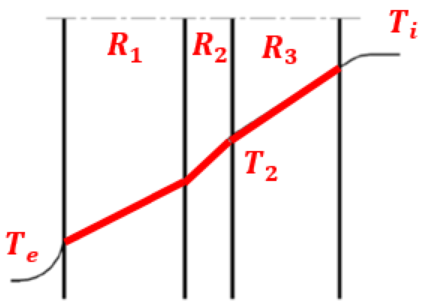
Procedure

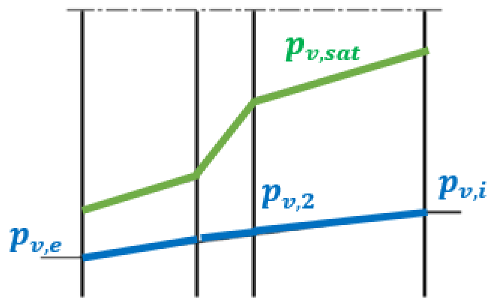


Glaser method

Calculation for each month

Find the water vapour pressure distribution, the temperature distribution and the saturated vapour pressure distribution





$$Z_j = \frac{s_{d.j}}{\delta_0}$$

$$T_j = T_e + \frac{\sum_{l=1}^{j} R_j}{R} (T_i - T_e)$$

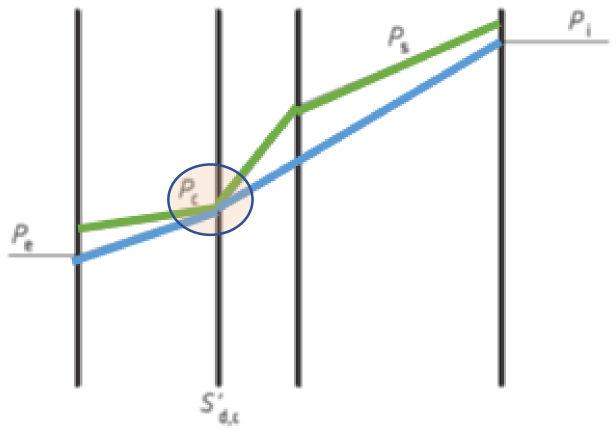
$$p_{v,j} = p_{v,e} + \frac{\sum_{l=1}^{j} Z_j}{Z} (p_{v,i} - p_{v,e})$$

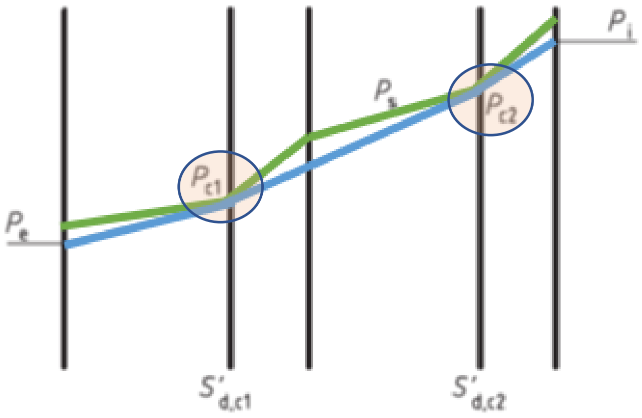
$$p_{sat,j} = \mathrm{f}(T_j)$$

Glaser method

Calculation for each month

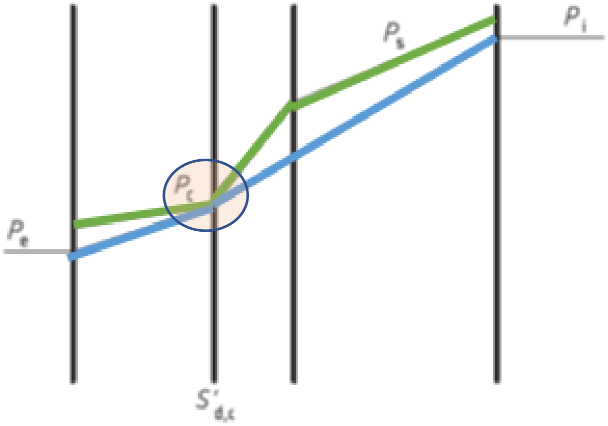
If $p_v > p_{v,sat}$ at any interface, assume that $p_v = p_{v,sat}$ and redraw the vapour pressure as a series of lines which touch, but do not exceed the saturation vapour pressure profile at as few points as possible.

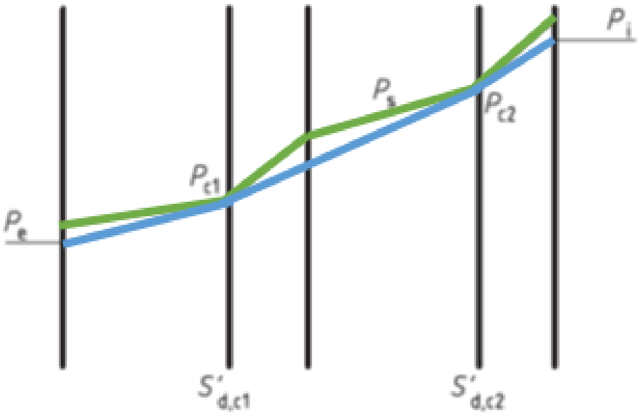




Glaser method

Condensation rate (1 interface)

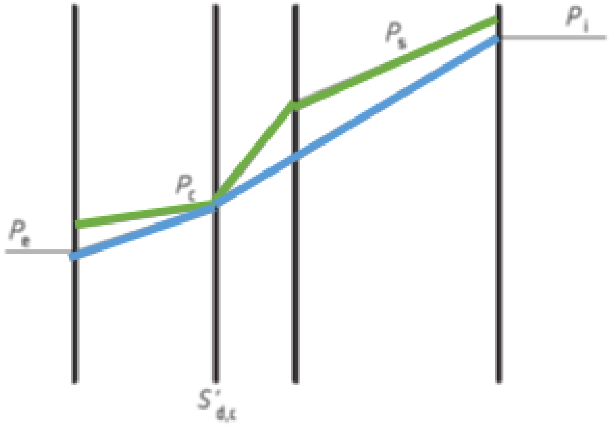


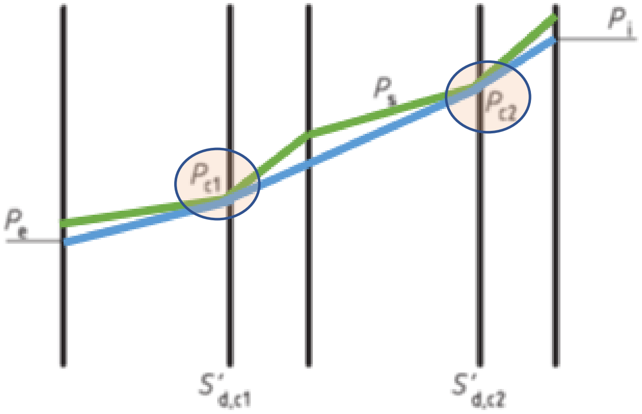


$$g_c = g_{c,in} - g_{c,out} = \delta_0 \left(\frac{p_i - p_c}{\sum_{i \to c} s_{d,j}} - \frac{p_c - p_e}{\sum_{c \to e} s_{d,j}} \right)$$

Glaser method

Condensation rate (2 interfaces)

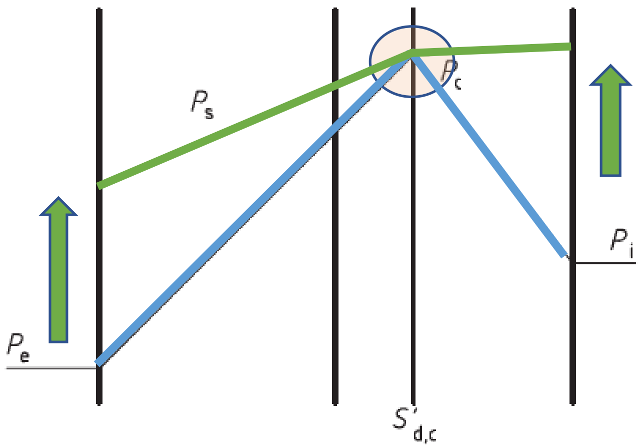




$$g_c = g_{c1} + g_{c2} = \left(g_{c1,in} - g_{c1,out}\right) + \left(g_{c2,in} - g_{c2,out}\right) = \ \ldots$$

Glaser method

Evaporation rate (1 interface)



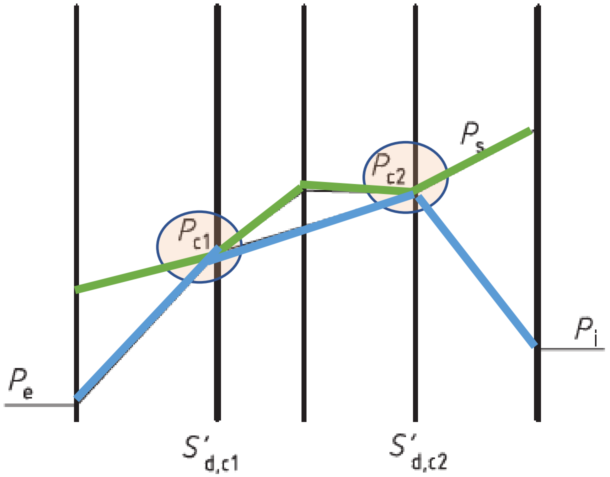
g_{ev} is identical to g_c

$g_c < 0$ → EVAP. ($g_c = g_{ev}$)
$g_c > 0$ → COND.

$$g_{ev} = g_{c,in} - g_{c,out} = \delta_0 \left(\frac{p_i - p_c}{\sum_{i \to c} s_{d,j}} - \frac{p_c - p_e}{\sum_{c \to e} s_{d,j}} \right)$$

Glaser method

Evaporation rate (2 interfaces)



g_{ev} is identical to g_c

$g_c < 0$ → EVAP. ($g_c = g_{ev}$)
$g_c > 0$ → COND.

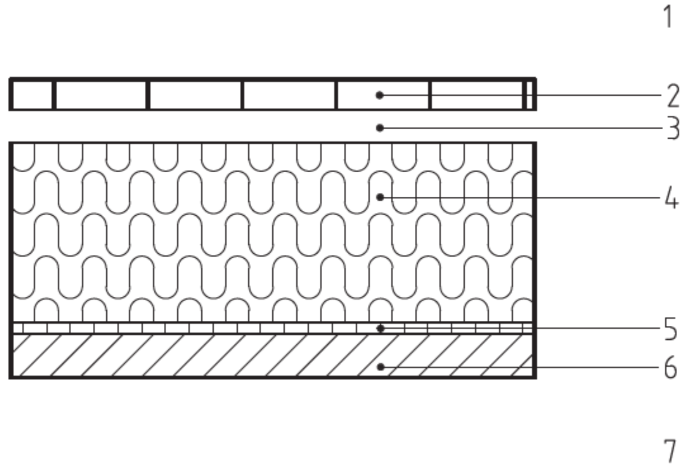
$$g_{ev} = g_{ev1} + g_{ev2} = \left(g_{c1,in} - g_{c1,out}\right) + \left(g_{c2,in} - g_{c2,out}\right) = \ \dots$$

Glaser method

Well ventilated cavities

If the element contains a layer which is well ventilated to the outside, do not consider the layers between the cavity and the outside. Assume:

$T_{air,cavity} = T_e$ and $R_{s,cavity} = R_{si}$



Key

1 external air
2 weatherproofing, 0,01 m
3 well ventilated cavity
4 insulation, 0,10 m
5 vapour check
6 liner, 0,012 m
7 internal air

Glaser method

Results

Report the results in one of the following forms:

(a) No condensation predicted at any surfaces at any months. The considered structure is **free of interstitial condensation**.

(b) Condensation occurs at one or more interfaces but **all the accumulated condensate rievaporates** so that there is no accumulation over the year.

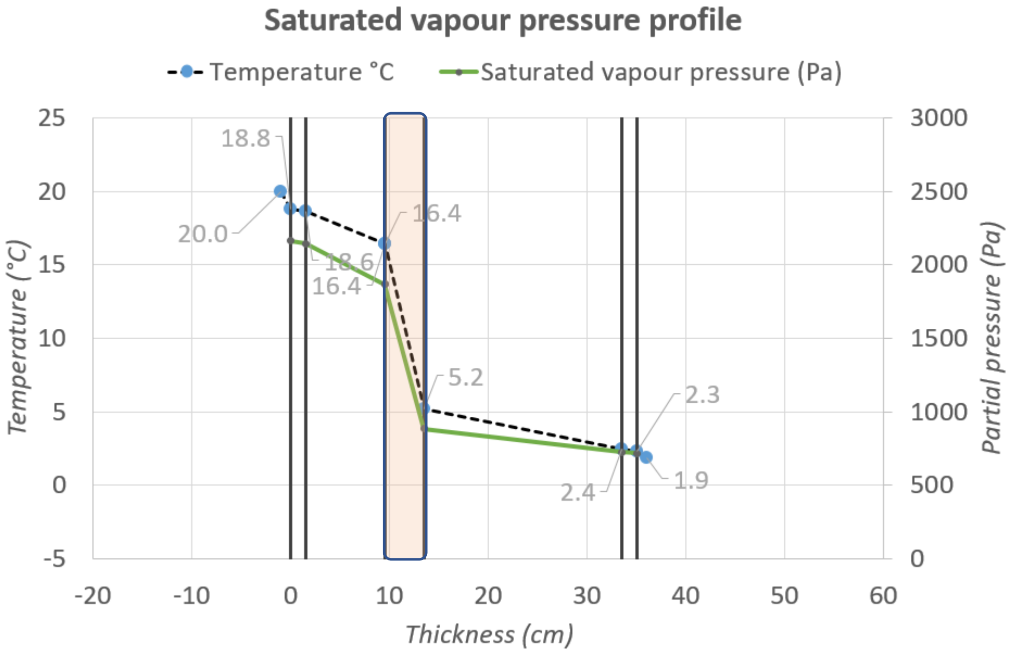
Report the maximum amount of condensate for each interface and the month during which the maximum occurred. Report risk of degradation of adjacent materials according to product specifications.

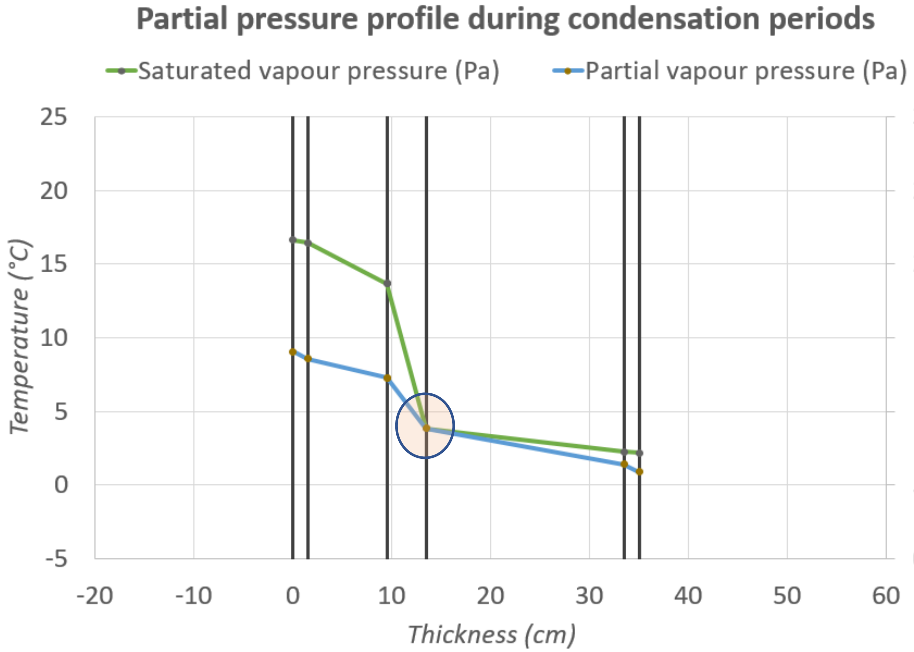
(c) **Condensate** at one or more surface **does not completely rievaporate**.

Report the maximum amount of condensate for each interface and the amount of condensate remaining after one year.

Glaser method

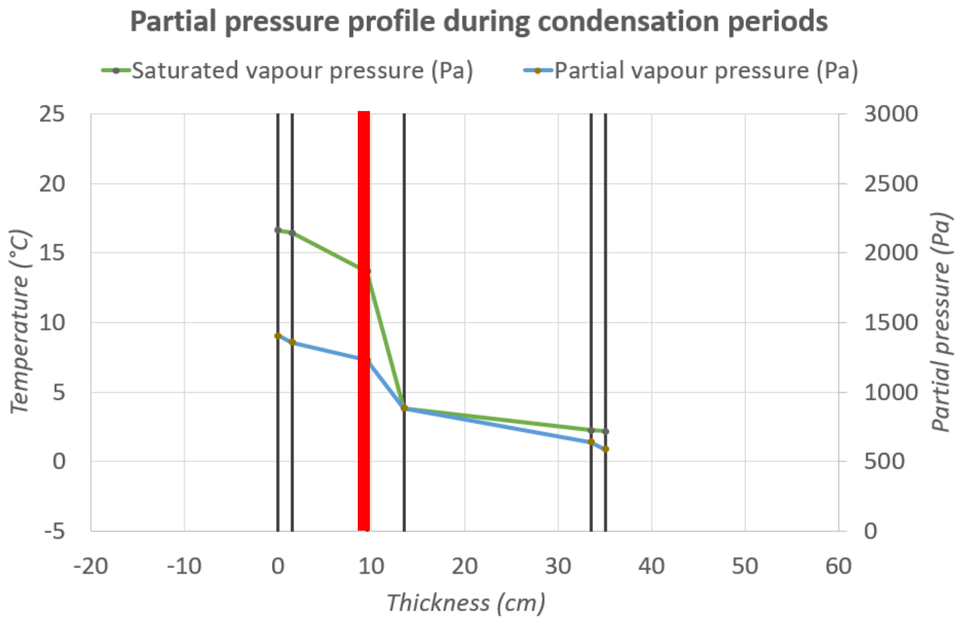
Protection against interstitial condensation



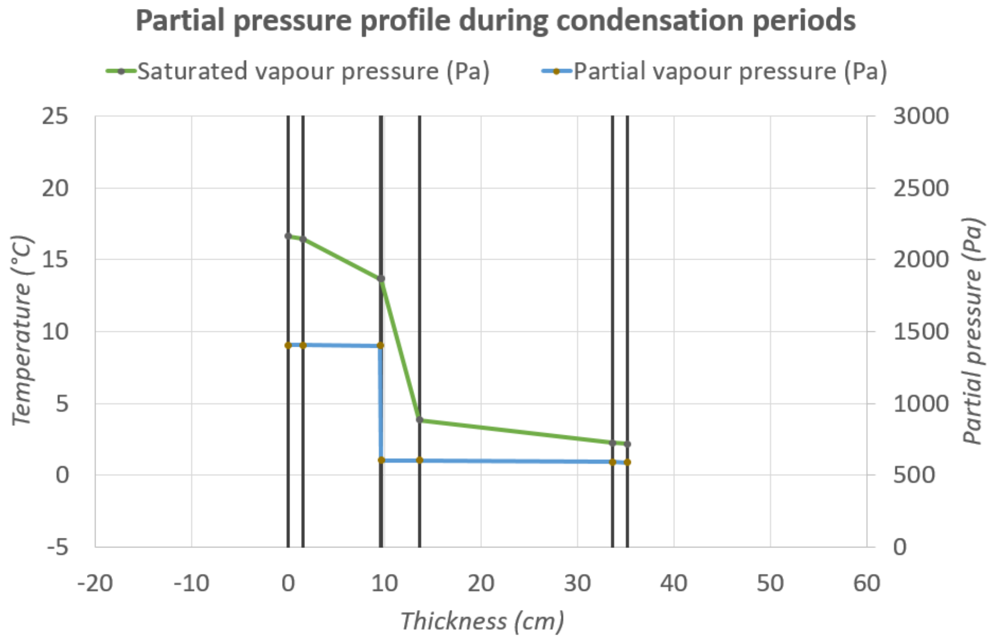


Glaser method

Protection against interstitial condensation

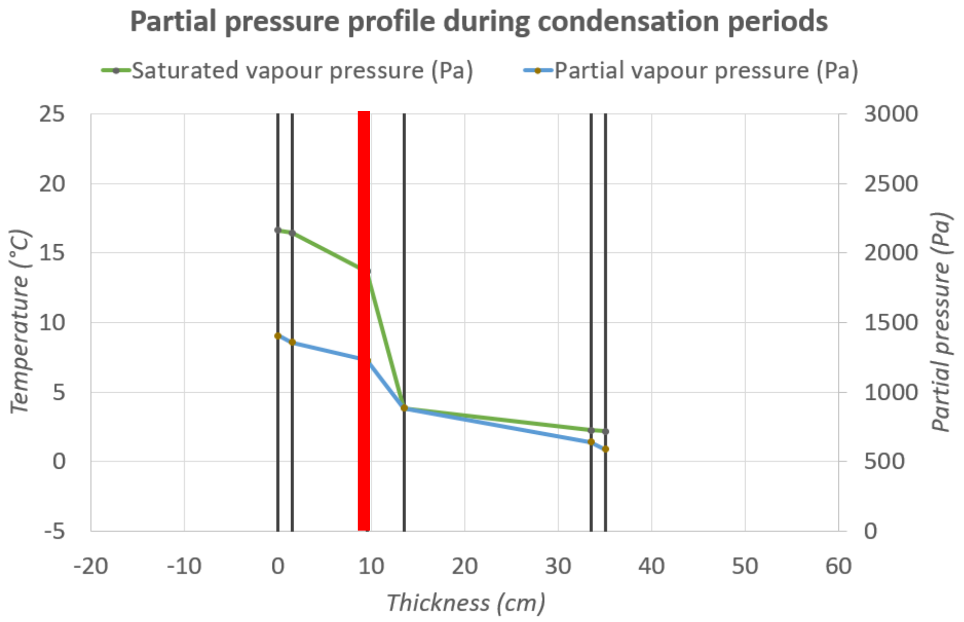


VAPOUR BARRIER (e.g. aluminum foil)



Glaser method

Protection against interstitial condensation

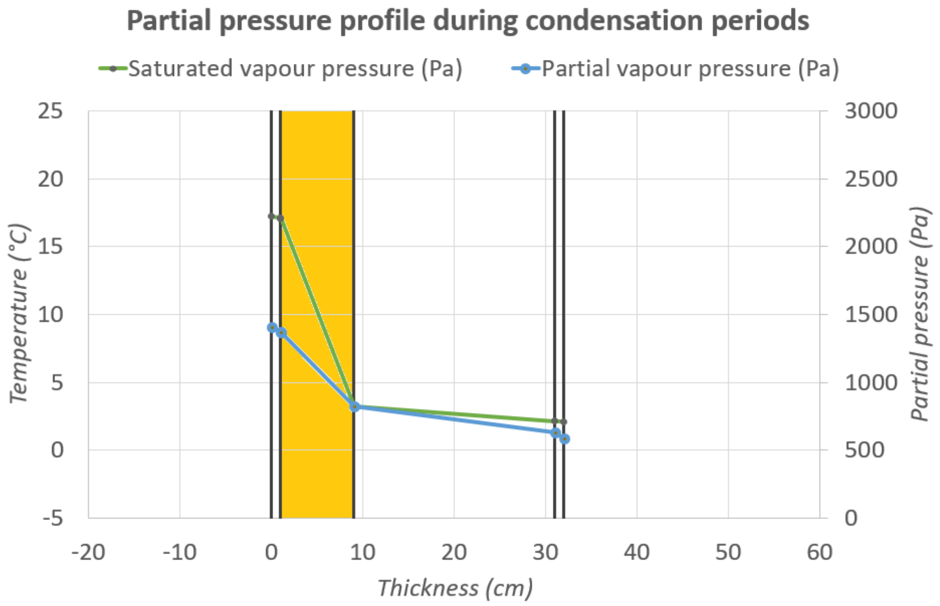


VAPOR BARRIER (Aluminum foil)

The position of the vapour barrier is of primary importance: it must be placed between the indoor environment and the thermal insulation material!

Glaser method

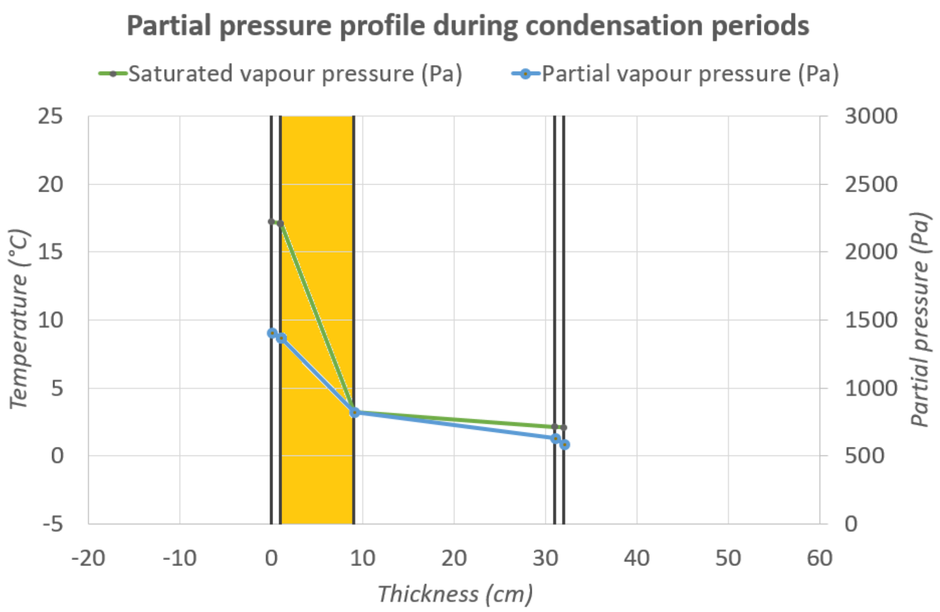
Protection against interstitial condensation

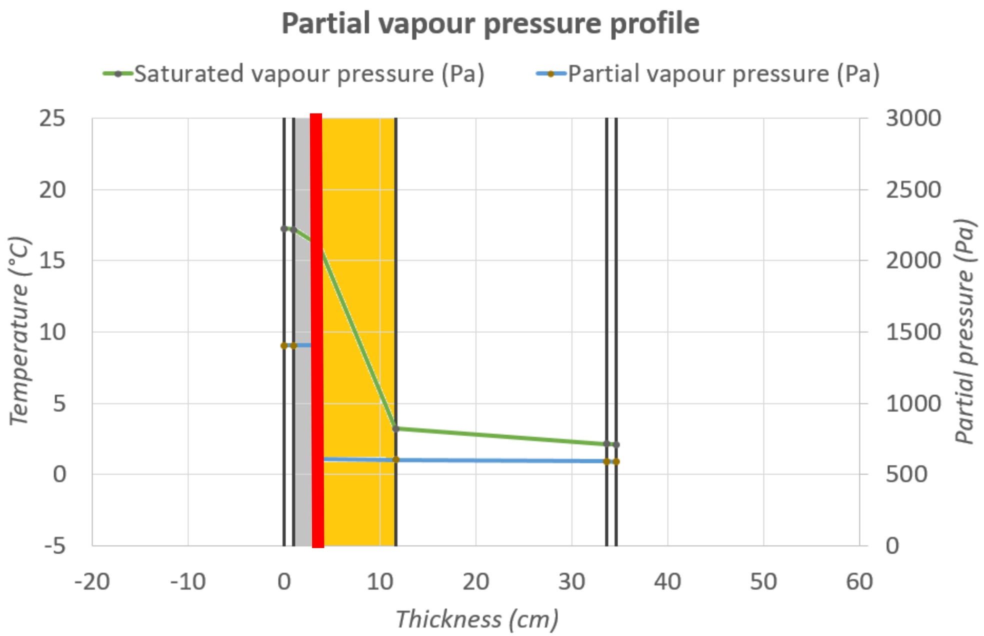


Interstitial condensation may be a problem for internal retrofits of old building envelopes!

Glaser method

Protection against interstitial condensation





VAPOUR BARRIER + DRYWALL DOUBLE PANEL

References

EN ISO 13788:2012 *Hygrothermal performance of building components and building elements - Internal surface temperature to avoid critical surface humidity and interstitial condensation - Calculation methods*

EN 15026 *Hygrothermal performance of building components and building elements - Assessment of moisture transfer by numerical simulation.*

UNI 10349-1:2016 Riscaldamento e raffrescamento degli edifici - Dati climatici - Parte 1: Medie mensili per la valutazione della prestazione termo-energetica dell'edificio e metodi per ripartire l'irradianza solare nella frazione diretta e diffusa e per calcolare l'irradianza solare su di una superficie inclinata. *[Italian]*